Final Study
* Image Processing *

lec : 1

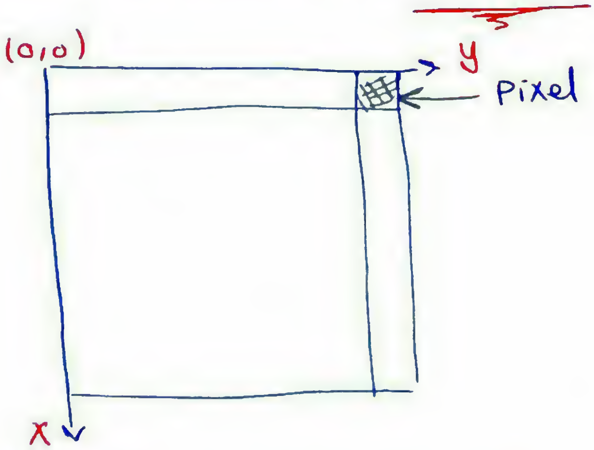
- Why digital Image processing?
  1- To improve the image quality to show it
  2- To process on image to get data from it
  process like : - Storage - Transmission - Representation

- Computer Vision & Image processing

	Computer Vision	Image processing
I/P	Images	Images
O/P	Knowledge of the scene	Images

↓
Methods : Using Image processing, machine learning, ...

- Image



⇒ $f(x,y)$
↑
f : intensity

- Digital image
  1- x, y, f ⇒ all finite (limited)
  2- x, y, f ⇒ discrete quantities (1, 2, 3, ...)

- To process an image, it must be a digital one.

- Colors
  ① black & white ∴ $f(x,y) = 0, 1$
  ② black & white & gray ∴ $f(x,y) = 0$ to 255
  ③ RGB ∴ 3 bytes each on $f(x,y) = 0$ to 255

- Electromagnetic Waves are a stream of massless particles, each traveling in a wave like pattern and moving at the speed of light. each massless particle contains a bundle (certain amount) of energy that is called a photon.

- $\boxed{\lambda = c/f}$

- $\boxed{E = h * f}$

- Image Processing and Other areas

  1. Low-level Processing

     small processing on the image

     Ex: acquiring and preparing an image of a piece of text.

  2. Mid-level Processing

     medium Processing on the image.

     Ex: Segmenting individual letters, extracting attributes.

  3. Height-level processing

     Large processing on the image.

     Ex: Making sense about the piece of text, making decision based on its contents, understanding the contents.

- Origin of digital image processing

  ⇒ The number of Color degree (distinct levels) and the distance between pixels are very important to get digital image with high quality.

  ⇒ Correcting Various types of image distortion inherent in the on-board television Camera on spacecraft is first digital image processing operation where digital computers were used in performing them.

~~Energy~~ Image Sources

1- Electromagnetic waves
2- Sound waves
3- Electron microscopes

1 Electromagnetic Waves

① Gamma Ray Imaging

a- Bone scan (For patients يحقن المريض بماده مشعه)
b- Positron emission tomography (PET) image (For Patients)
c- Cygnus loop (صوره لمجموعه نجوم وهنا الجسم هو مصدر الاشعاع)
d- Gamma radiation (bright spot) from a reactor value.

② X-Ray Imaging

a- Chest X-ray (For patients)
b- Aortic angiogram (image of blood vessels using catheter)
c- Head CAT (Computerized axial tomography)
d- Circuit board (check missing / broken parts)
e- Cygnus loop.

③ Ultraviolet Imaging

a- Normal corn
b- smut corn (sick)
c- Cygnus loop.

الأشعه فوق البنفسجيه نفسها غير مرئيه لكن عند اصطدام فوتون منها بالكترون من ماده فسفوريه تشع ضوء أحمر يمكن رؤيته

→ The ultraviolet light itself is not visible but when a photon of ultraviolet radiation collides with an electron in an atom of fluorescent material, it elevates the electron to a higher energy level. Subsequently, the excited electron relaxes to a lower level and emits high in the form of a lower-energy photon in the visible (red) light region.

④ Visible / infrared Imaging

يستخدم مصدر ضوء عادي

examples

⟹ Multispectral imaging

(1) Taxol
(2) cholestrol
(3) Micro processor
(4) audio CD
(5) Super Conductor
(6) Nickel oxide

To generate many images for the same object using different energy sources, here we can note that the quantity of the image for the same object is different based on the energy source.

App: weather observation and prediction. ①

② أخذ صوره ليليه للأرض لتحديد استهلاك الكهرباء على مستوى العالم

③ الدوائر الكهربيه / المصانع > missing compenents

④ thumb print وتحديد نوع العمله ولوحه السياره

* Visible / infrared light used to make remote sensing

Automated Visual inspection of manufactured goods

a- missing component in a controller board.

b- missing pills.

c- bottels that are not filled up to an acceptable level.

d- Bubbles in clear- plastic product.

* addition exampler of imaging in the Visual spectrum

a- Thumb print

b- paper currency

c- Automated license plate reading.

5 Microwave Imaging

→ Radar

- radar emits it's own microwave pulses and receive the returned microwave through antenna. Computer processing is used to make useful images.

6 Radio Imaging

- magnetic resonance imaging (MRI) (for patients)
تصوير الرنين المغناطيسي

2 Sound Waves

1 Ultrasound Imaging

- Sonar System.

2 InfraSound

- geological exploration (minirel and oiL)
- industry

3 Electron microscopes

* شعاع الكترونى يطلع من مصدر ثم يجمع من خلال عدسات lenses ليصبح thin beam لتركيزها ع العينه ، تحدث تفاعلات بين الالكترونات والعينه مكونه الصورة

explain

Two types

↳ TEM

↳ SEM

Ultra Sound Imaging

السونار

1_ The ultrasound System (a Computer, ultrasound probe consisting of a source and receiver, and a display) transmits high-frequency 2-5 MHz sound pulses into the body.

2- The sound waves travel into the body and hit a boundary between tissues. Some of the sound waves are reflected back to the probe, while some travel on further until they reach another boundary and get reflected.

3. The reflected waves are picked up by the probe and relayed to the Computer.

4. The machine calculates the distance from the probe to the tissue or organ boundaries using the speed of sound in tissue 1540 m/s and the time of each echo's return.

5_ The system display the distances and intensities of the echoes on the screen, forming a two-dimensional image.

Imaging Using Electron microscopes

- A stream of electrons is produced by an electron source and accelerated toward the specimen.
- This stream is Confined and Focused using metal apertures and magnetic lenses into a thin, focused, monochromatic beam.
- This beam is focused onto the sample using magnetic lens.
- interactions occur inside the irradiated sample, affecting the electron beam.
- These interactions and effects are detected and transformed into an Image, much in the same way that light is reflected from, or absorbed by, objects in a scene.

<u>EX:</u> Tungsten filament following thermal failure.
Image of damaged integrated circuit.
Slide Projector
TV raster scan.

Restoration & Enhancement

restoration: Objective Operation
→ This Operation bases on the used application

enhancement: Subjective Operation.
→ This operation bases on the User (man)

Fundamental Steps in digital image processing

Can be divided into 2 Categories (groups)

1. Methods whose Inputs & Outputs are Images
2. Methods whose inputs are images and whose output are attributes (Features are extracted From those Images)

الخطوات التاليه هى كل الخطوات التى تمر بها أى صوره ولكن ليس بالضروره لكل صوره أن تمر بكل الخطوات وهذا ع حسب البرنامج المستخدم فى صناعه هذه الصورة

Steps

[1] Image Acquisition

Could be as simple as giving an image that's already in digital form.
Generaly, the image acquisition state in values preprocessing such as scalling.

[2] Image Enhancement

Is to bring out details that's simply to highlight Certen Features of interest in an image.
ex: increase or decrease the Contract (subjective)

3 Image Restoration

Is based on mathematical or statistical model Image. (Objective)

4 Color Image Processing

- Color is used as the basies for extracting.
- Features of interest in an image.

مثال : تفاح ، مانجو على خط انتاج ، بيزبيتم سرفلال اللـــون

5 Wavelets and Multiresolution Processing.

- Are the Foundation for representing images in varies degrees of resolution. توضع الصوره في أكثر من resolution
- Basicaly is used in image Compression.
- Make the image ready to be Compressed.

6 Compression

- decrease the image size to be easy to work with it
- Reduces the storage required to save an image or the bandwidth require to transimit it. تتعامل مع المساحه المطلوبه لتخزين الصوره وكذلك نقلها ع bandwidth أقل
- (Famous image type JPEG)

7 Morphological Processing.

- Depends on logical & <u>mathematical operation</u> for <u>extracting</u> image <u>componants</u> as boundry that are useful in the representation and description of sheet.

* boundary → objects الحد الفاصل بين

* Skeleton → الحيز الذي يشغله الـ object في الصوره

8 Segmentation.

- partition an image into it's consequent parts or objects.

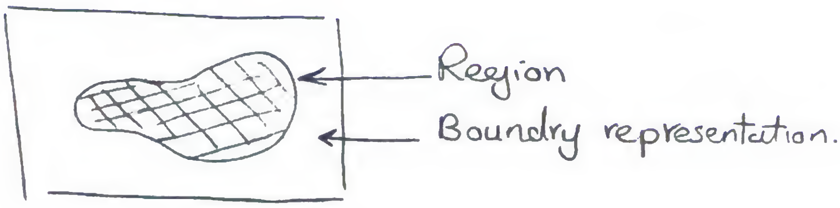
Divide the image into small parts.

9 Representation & Description.

- Extraction of the set of pixels at the boundry of objects or the pixels in region inside the boundry.

  * This pixels are used as features that prepared for object recognation.

  (Feature extraction, Feature Selection)



10 Object Recognation.

The process that assignes a lable to an object based on it's Features (altributes, descriptors).

→ **Knowledge Base:**

Controls the interaction between the different modules. and determine regions in the image.

→ **Mass Storage:**

1) Short term → Storage for used during processing
   - RAM, Frame buffer

   حافظه مؤقتة خلال عمليه ال process

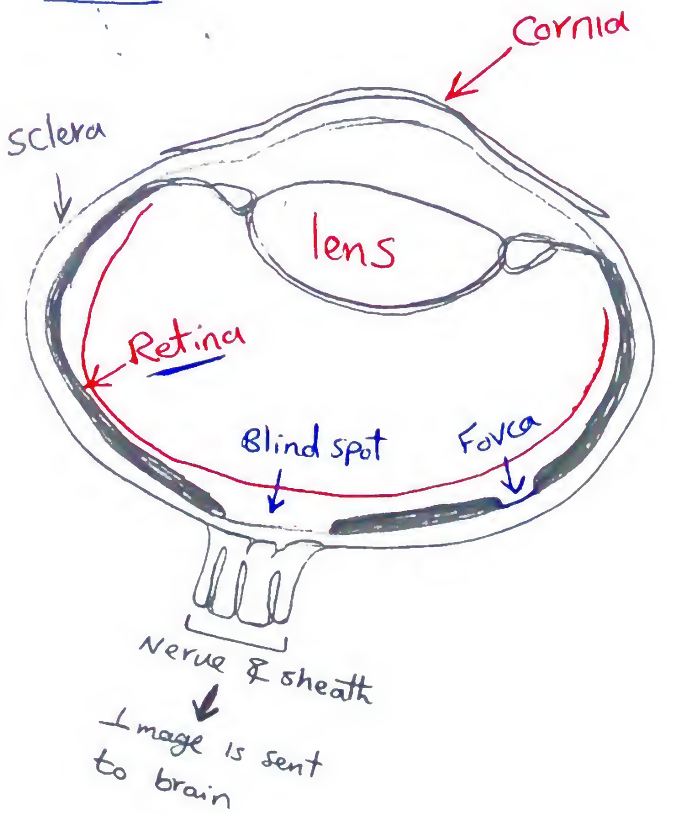
2) Online Storage for relatively fast recall:
   → magnetic disk, optical media Storage.

3) Archival Storage (infrequent need for access)
   → magnetic tapes, optical disks.

* **Hard Copy**
  ex: printer
* **Image processing Software.**
  ex: matlab software.

lec : 2

• Eye



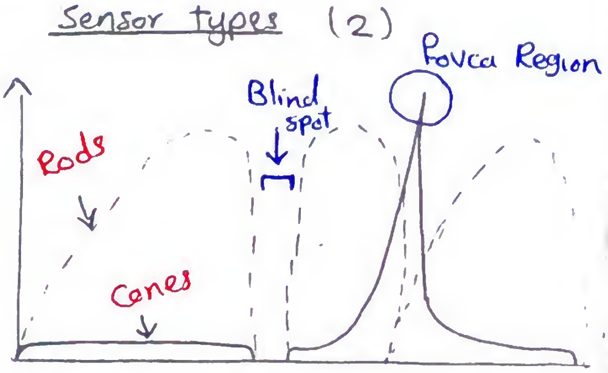
* eye main parts

① Cornia & sclera (eye cover)

② lens & Iris (observe lights and collect image)

③ Retina has sensors

Sensor types (2)

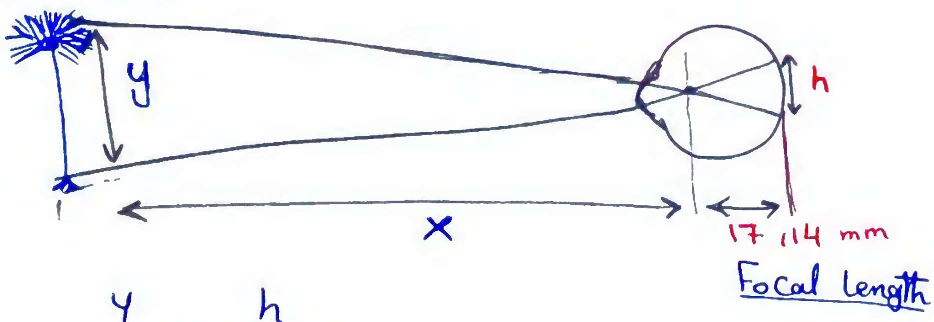


① Rods (Take large size of retina)
low illumination (scotopic vision)
work at night

② Cones (centralized in Fovca Region)
Color (photopic) vision
تعمل نهارًا

* **Blind Spot**: the portion of retina where neither cones nor rods exist.

• Image Formation in the Eye



$$\frac{y}{x} = \frac{h}{14 , 17 \text{ mm}}$$

14: if $x < 3$ m

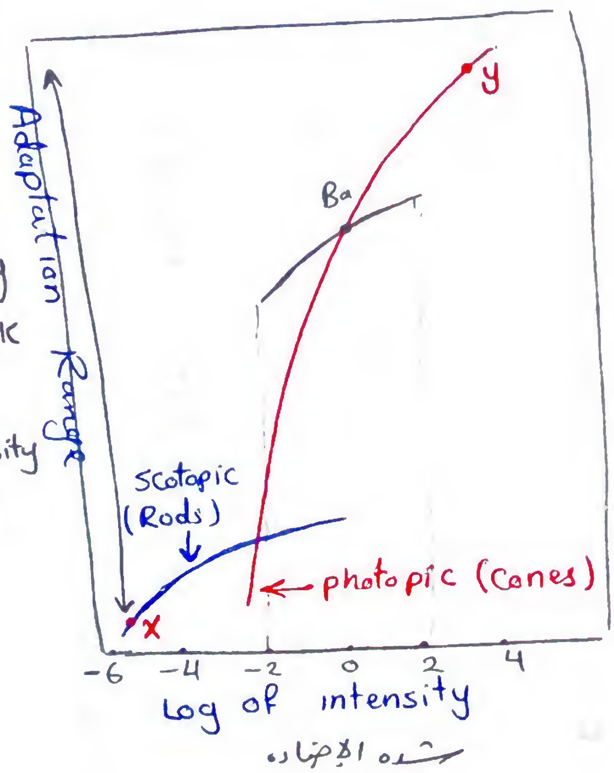
17: if $x > 3$ m

• Brightness adaptation and discrimination:

تكيف العين مع شدة اضاءة المكان حتى نستطيع الرؤية

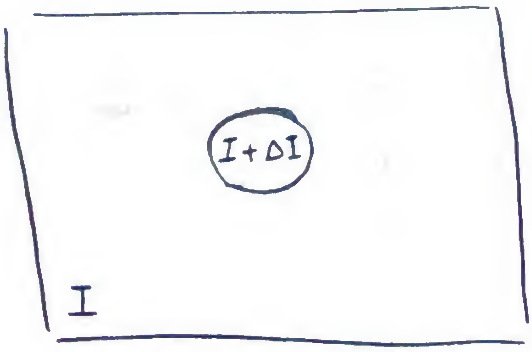
مدى احساس العين بالفرق في شدة الاضاءة (subjective)

* intensity [-6, 0]
  * low intensity
    So Rods work
* intensity [-2, 4]
  * high intensity
    So Cones work
* For point Ba the range of intensity will be [-2, 2]



* Brightness adaptation means that we can see in dark room (low intensity) where rods work (X-Point) and also see in the very light room (high intensity) where Cones work (Y-Point)

Basic experimental setup used to Characterize brightness discrimination (change of intensity)



$\Delta I = I_{new} - I_{old}$

$$\boxed{\text{Weber ration}: \frac{\Delta I}{I}}$$

→ at first : light of the room is I

→ Then we change the light I by ΔI

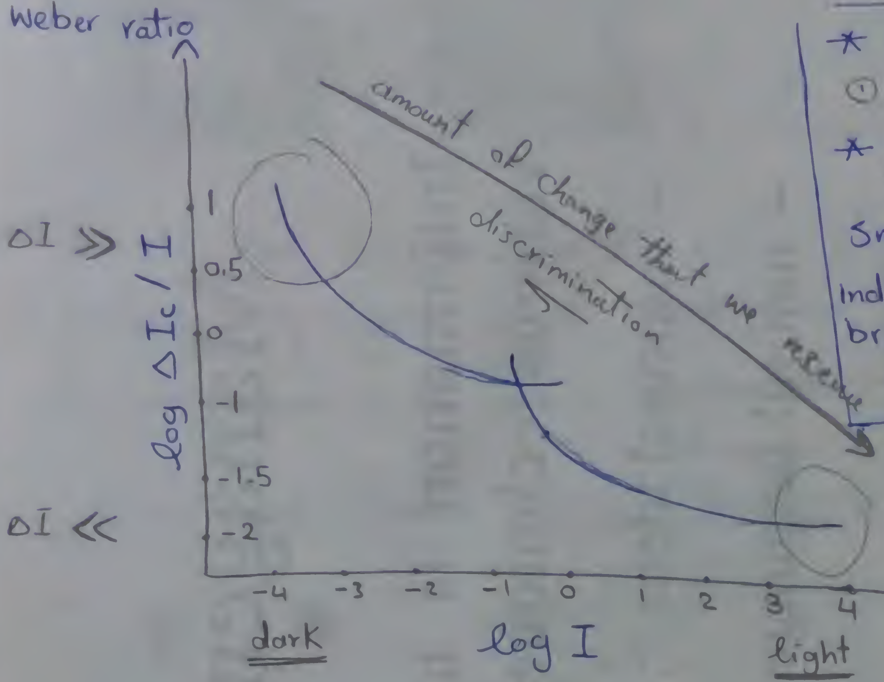
ΔI up → makes the room lighter

ΔI down → makes the room darker

→ amount of change that we receive (discrimination) dependes on I

* weber ration = $\frac{\Delta I}{I}$ (متغير تابع)
* intensity = I (متغير مستقل)

→ Typical Weber ratio as a Function of intensity



* $\Delta I = I_{new} - I_{old}$

① $I_{new} \simeq I_{old}$

* ΔI = small
$\frac{\Delta I}{I}$ = small

?

weber ratio

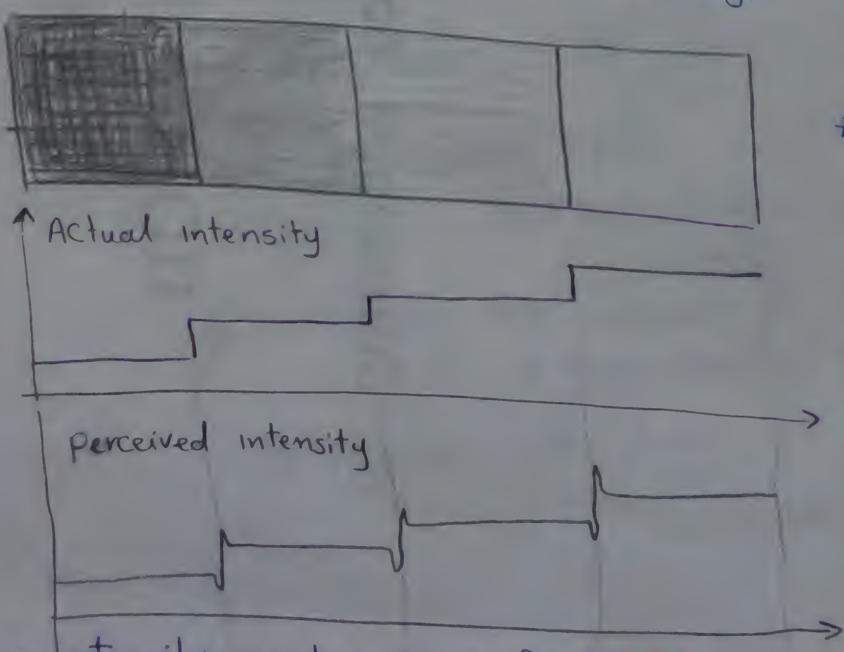
Small Value
indicates good
brightness
discrimination

Large Value
indicate poor
brightness
discrimination

* this mean that in dark room, we need big change in intensity ΔI to get discrimination. and also on light rooms.

* Finally, we need big weber ratio to sense the change of intensity.

→ subjective brightness: is the intenisty as percived by human Visual system and is a logithmic Function of the Light intensity incident on the eye.



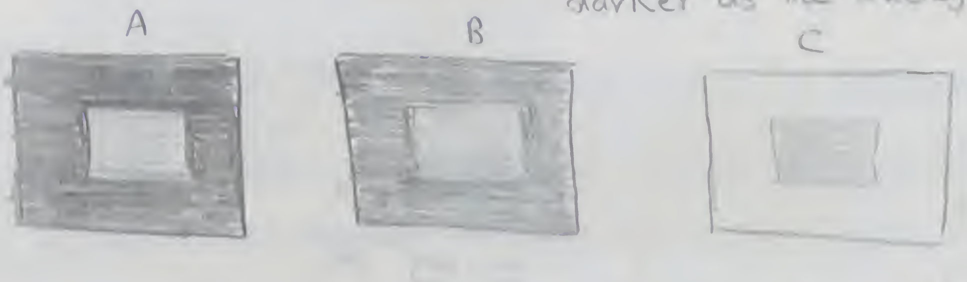
* the Visual system tends to undershoot or overshoot around the boundary of regions of different intensities

Mach Bands

عند لحظه انتقال العين بين مستوين
مختلفين في شده الاضاءه يحدث
undershoot أو overshoot

** intensity is not a simple Function !! of actual intensity.

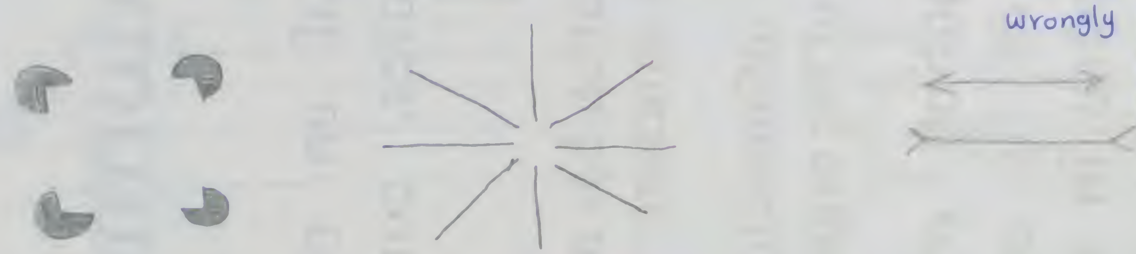
[2] Simultaneous Contrast : objects have the same intenisty but app[ear] darker as the background becomes light[er]



All the inner squares have the same intensity, but they appear progressively darker as the background becomes lighter

* inner square in C appear darker than in A

- Some well-Known Optical illusion الخداع البصري : The eye fills in a non-existing information or wrongly perceives geometrical properities of an object



* To create an Image (Condition: wave length "λ" الطول الموجي $\leq$ object diamter)

EX: IF object diamter 10^{-9} so we can use X-rays or gamma rays to make an Image to this object.

Light Characterization

1- Monochromatic أحادي اللون (achromatic) light (no Color)

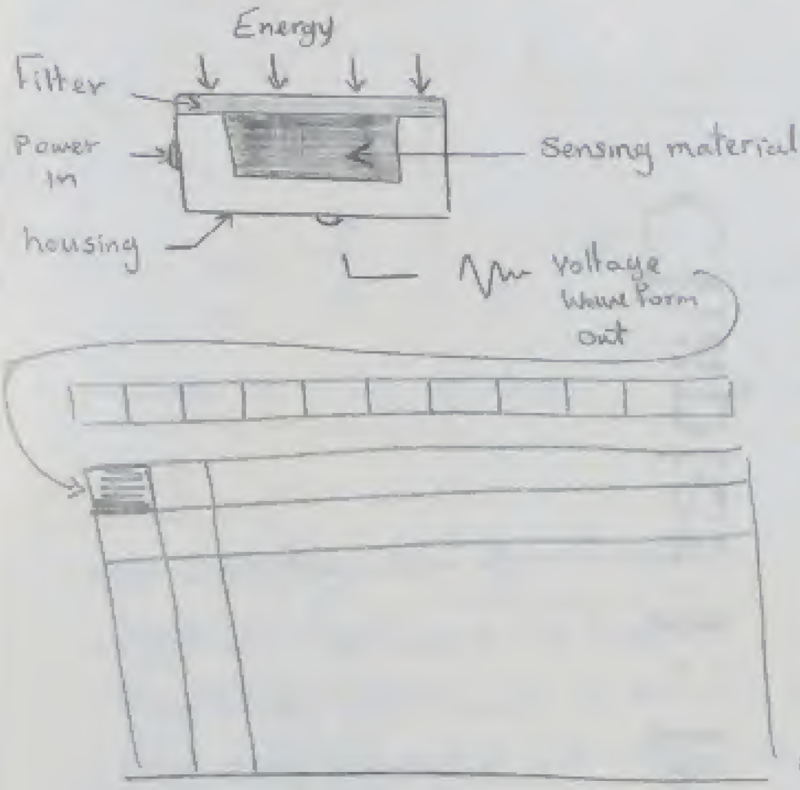
- intensity / gray level تدرج (pixels Value = intensity Value (0,1))

2- Chromatic (Colored) light تدرج

- Radiance : total amount of energy that flows from the light source (watts)
- Luminance: the amount of energy an observer perceives from a light source (Lumens or Lm)
- Brightness : subjective.

Sensor

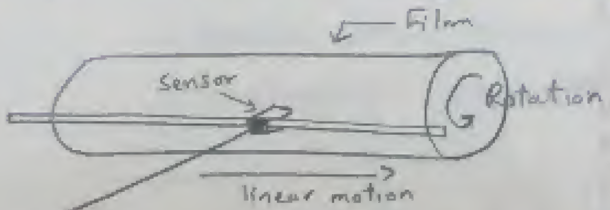
* human Eye have Cons and rods (million numbers of sensors)
* General Sensor arrangement used to transform illumination energy into digital image.



* This arrangement gives a spatially discrete image, the output voltage is passed into a A/D converter to obtain a digital image
* A Filter might be used to filter illumination that passes to the sensor. For example a green filter makes the response of the sensor to green illumination higher than other colors.

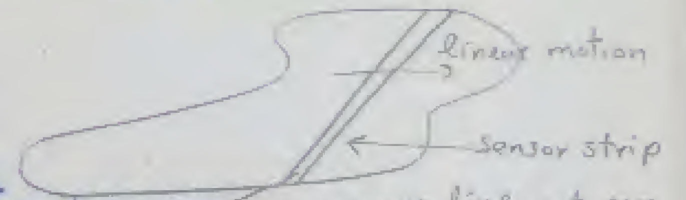
$m \times n$ array , $m \times n$ = no. of sensors

Image acquisition: Single Sensor / Sensor Strip



→ one image line out per increment of rotation and full linear displacement of sensor from left to right

Drum with a Single Sensor

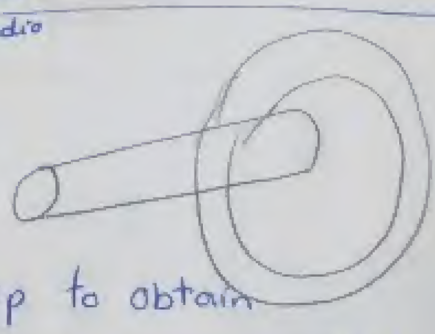


Apps

1. Flat bed scanners
2. Airborne imaging
   التصوير الجوي
3. CAT → x-rays
4. PET → Gamma
5. MRI → Radio

→ one image line out per increment of linear motion

Strip Sensor



Ring Strip to obtain Crossectional Image in a three dimensions object.

→ Used in digital cameras 16 milion sensor

* Simple Image formation model

$$0 < f(x,y) < \infty$$

$$f(x,y) = \underbrace{l(x,y)}_{\substack{\text{illumination} \\ \text{كمية الضوء الساقط}}} * \underbrace{r(x,y)}_{\substack{\text{reflectance} \\ \text{depend on object}}}$$

intenisity

$$\therefore f(x,y) = l(x,y)\ r(x,y)$$

$$0 < l(x,y) < \infty$$

$$\underset{\text{black}}{0} < r(x,y) < \underset{\text{wight}}{1}$$

wight ← لو عكس كل الالوان

black ← لو امتص كل الالوان

$$l = f(x_0, y_0)$$

$$L_{min} \leq l \leq L_{max}$$

$$0 \leq l \leq L-1$$

normalization

$$L_{min} = r_{min} * l_{min} \qquad L_{max} = r_{max} * l_{max}$$

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lec : 3

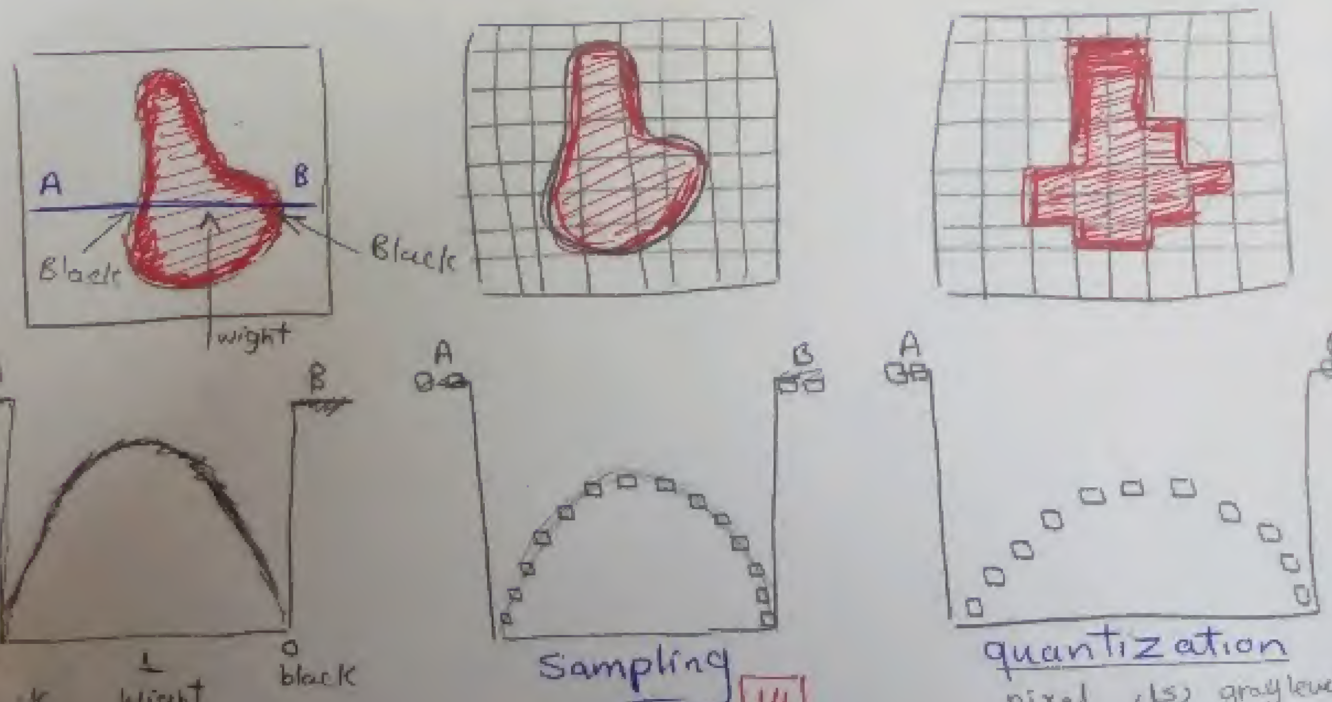
· Image Sampling and quantization

عدد ال periode ثم نحول sampling

- Spatial : Continuous to discrete (sampling)
- Amplitude : Continuous to discrete (quantization)
- How many samples? On which that depends
  - Single sensor acquisition
  - sensing strip acquisition
  - sensor array acquisition
  - Continuous image digitization.

* Sampling is the digitizing coordinates values.

* quantization is the digitizing process of the amplitude values.



Sampling

quantization

تحديد gray level لكل pixel

Mechanical Increment Controls Sampling Frequency

* In Single Sensor
  arrangement sampling is accomplished by selecting the no. of individual mechanical increments at which we activate the sensor to collect the ...

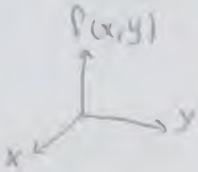
* In a Strip sensor
  The no. of sensors in the strip establishes the sampling limitations.

* In a sensor array
  The no. of sensors in the array establishes the sampling limitations.

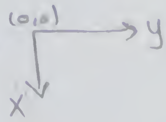
Image representation

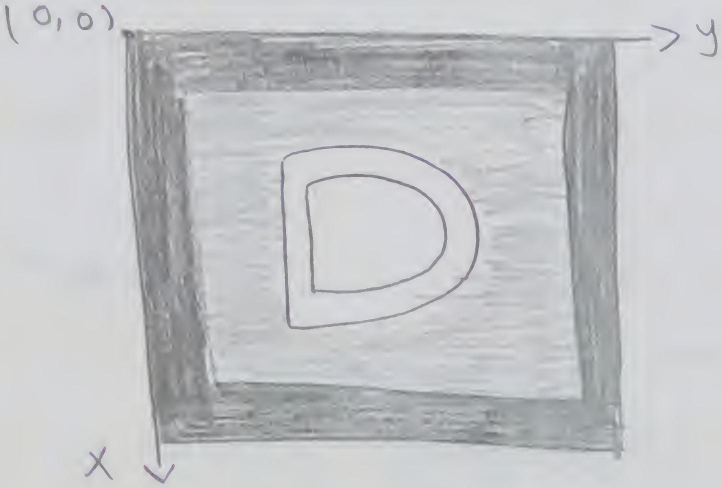
3 representation

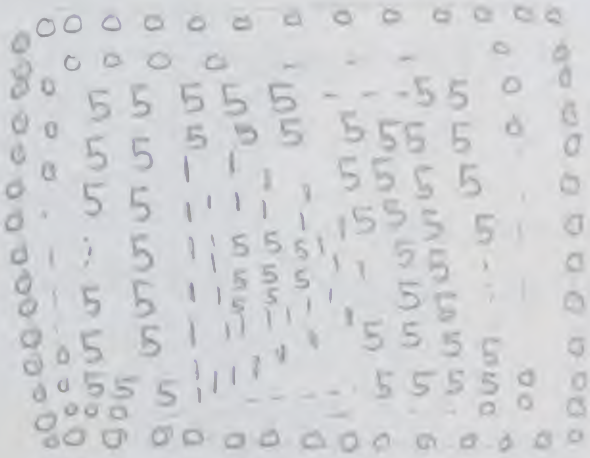
- Surface (~~standard right-hand~~ Cartesian)



- Image (for human)
- Array (M x N) (for algorithms)







We take 5 for gray

3 bytes

0 → black

255 → wight

(0 → 255) → gray

$L = 2^K$

↑ no.of gray levels

Contrast = highest gray level − lowest gray level

* Maximum and Minimum intensity levels

$$\text{Dynamic range} = \frac{\text{Max intensity level}}{\text{Min intensity level}}$$

gray level (above "intensity" in numerator); ~~gray level~~ (above "intensity" in denominator)

Max intensity level ← Controlled by saturation

Min intensity level ← Controlled by noise.

* Image Size & Space for Storage

$$b = \underbrace{M * N}_{\text{how many pixels per unit distance.}} * \underset{\text{bit image}}{K}$$

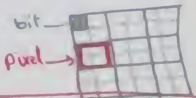
M: rows, N: Columns

* Resolution

Intensity: no.of bits used to quantize the intenisity

* كل pixel تخزن في كام bit

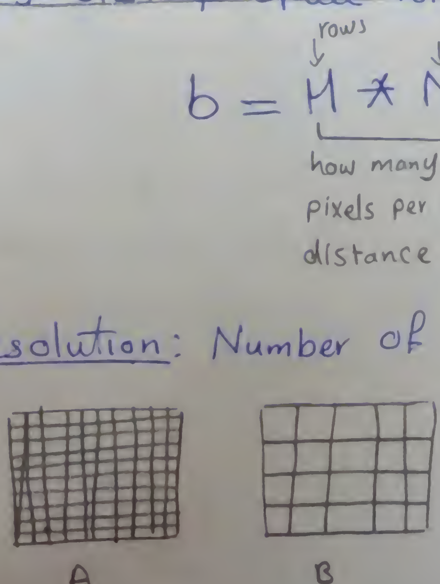
Spatial: no.of pixels per Unit distance



SR = 9 pixels

IR = 4 bit per pixel

* Resolution: Number of gray level



no.of bits (K) in A > K of B

$\boxed{\text{Image A is more clear and resolution is very high}}$

15

* spatial resolution is a measure of the smallest discrinable detail in an image

Nomber of Pixels per Unit distance (dpi)

Increasing Samples or levels ?

* levels of details
  - low (ex: Face)
  - middle (ex: cameraman)
  - High (Crowd)

* in images of large amount of details, a few intensity levels may be sufficient. (images of high details is represented with low no. of gray levels)

· Image Resizing and Interpolation (zooming, shrinking, rotating, geometric correct)
is the process of using known data to estimate values at unknown location.

→ Interpolation Methods

[1] Nearst Neighbour

هنا لو فيه pixel غير معلومه القيمه بأخذ قيمتها من الـ pixel الجار

→ Zooming

· Image 500 X 500 , X = 1.5 ⟹ we get image 750 X 750

[2] Bilinear interpolation

For a pixel with Coordinates x, y ⟹ $v(x,y) = ax + by + cxy + d$

we need $U(x,y)$ ⟹ نعوض في أقرب جيران لـ x,y في المعادله نحصل ع 4 معادلات نحلهم مع بعض نحصل ع a,b,c,d

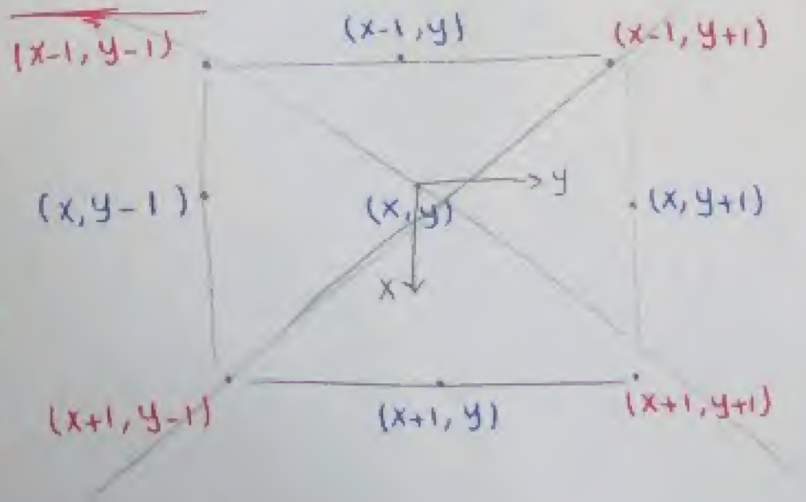
نعوض في المعادله نحصل ع V(x,y) والحل ده أفضل من حيث quality

[3] Bicubic interpolation

$$U(x,y) = \sum_{i=0}^{3} \sum_{j=0}^{3} a_{ij} \, x^{i} \, y^{j}$$

نستخدم أقرب 16 جار للنقطه (x,y) وتستخدم هذه الطريقه في Adobe photoshop

For a pixel P(x, y)



$N_4(P)$ ⟹ Four neighbors of P
(x-1, y) (x, y-1) (x, y+1)
(x+1, y)

$N_D(P)$ ⟹ Four nearst neighbors on the diamter (x-1, y+1)
(x-1, y-1) (x+1, y-1) (x+1, y+1)

$N_8(P) = N_4(P) \cup N_D(P)$
eight nearst neighbors

→ Pixel take Value $V = \{0,1\}$ in gray level (no color)

$V = \{0 \to 255\}$ ⇒ gray image

$V = \{$ 3 bytes each $0 \to 255\}$ ⇒ colorred Image

* Adjacency : Relation between pixels

[1] 4 - adjacency

Two pixels p, q with values from V are 4-adjacent if q is in the set $N_4(P)$

[2] 8 - adjacency

— IF q is in the set $N_8(P)$

[3] m - adjacency

IF ① q is in $N_4(P)$

OR ② q is in the set $N_D(P)$ and $N_4(P) \cap N_4(q)$ has no pixels whose values are from V.

---

lec : 4

* Mathematical Operation On Images

$$A = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} , \quad B = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix}$$

[1] Matrix Operation

$$A \times B = \begin{bmatrix} a_{11}b_{11} + a_{12}b_{21} & a_{11}b_{12} + a_{12}b_{22} \\ a_{21}b_{11} + a_{22}b_{21} & a_{21}b_{12} + a_{22}b_{22} \end{bmatrix}$$

[2] Array Operation.

$$A \times B = \begin{bmatrix} a_{11}b_{11} & a_{12}b_{12} \\ a_{21}b_{21} & a_{22}b_{22} \end{bmatrix}$$

So we use Array Operation to multiply each pixel with its opessit in the other Image

* Linear & non Linear Operations

an operation H on an image $f(x,y)$ to produce an image $g(x,y)$

H is linear if :

1- $H[a f(x,y)] = a\, H[f(x,y)]$ → Homogenous

2- $H[a_i f_i(x,y) + a_j f_j(x,y)] = a_i H[f_i(x,y)] + a_j H[f_j(x,y)]$ → Additive.

→ The Sum of all pixel Values in an Image

$$\sum [a_i f_i(x,y) + a_j f_j(x,y)] = \sum [a_i f_i(x,y)] + \sum [a_j f_j(x,y)]$$
$$= a_i \sum [f_i(x,y)] + a_j \sum [f_j(x,y)]$$

∴ The Sum operation is linear

→ The maximum pixel Value in an image

$$\text{Max}\left\{(1)\begin{bmatrix} 0 & 2 \\ 2 & 3 \end{bmatrix} + (-1)\begin{bmatrix} 6 & 5 \\ 4 & 7 \end{bmatrix}\right\} = \max\left\{\begin{bmatrix} -6 & -3 \\ -2 & -4 \end{bmatrix}\right\} = -2$$

$$(1)\,\text{Max}\left\{\begin{bmatrix} 0 & 2 \\ 2 & 3 \end{bmatrix}\right\} + (-1)\,\text{Max}\left\{\begin{bmatrix} 6 & 5 \\ 4 & 7 \end{bmatrix}\right\} = (1*3) + (-1*7) = -4$$

∴ Max is nonlinear.

---

* Arithmetic Operation

arithmetic operations on Images are done as array operation.

$(+ \; , \; - \; , \; \times \; , \; \div)$

• Addition App

→ To remove noise from an image we get more images for the same object and take the average of each pixel in the main image with the opessite pixels in the other images.

- The more Images we take , the better quality we get
- we take the main Image by a Camera And put noise on it using gaussian noise

Subtraction App

Idea : We sub 2 image to show difference between them
at first we have goldn Image without missing components then we get live image with missing components , when we sub 2 images we get image has only the missing component

1. Idustry — ق المطابع
2. Medical
   - ① image using TV Camera (Mask image)
   - ② inject the patient with material that show X - rays
   - ③ then we get live Image
   - ④ Sub live image from mask image
   - ⑤ make enhancement to get pure image.

Multiplication App

1 Shading Correction

① image with shading generated by the sensor (image a)

② shading obtained by taking an image for a scene with constant intensities using the same sensor (image b)

③ multiple image a with $\frac{1}{\text{image}\,b}$ $\left(\text{image with shading} * \frac{1}{\text{shading}}\right)$

④ we get image C without shading.

2 Masking

. We need determined object in an image so we multiple the main Image with unColored image (black - wight) has black part and wight part where we multiple the part of the object we need by 1 (wight part) and the other part of the image by 0 (black)

So, we get the object only.

* After an arithemetic operation, we may get an image with negative inten Value. Values greater than maximum possible intensity value used for storing the image, the following operation rescale and normalize the image to conse the full range of the mathematical operation

→ Choose the minimum value and sub it from all pixels value so we get image with minimum intensity equal to zero

$$f_m(x,y) = f(x,y) - \text{Min}[f(x,y)]$$

then scale the image according to the number of bits per pixel

$$f_s = L\left[f_m(x,y) \div \text{Max}[f_m(x,y)]\right]$$

where $L = 2^K$, K no. of Bits / Pixel

produce an image whose pixel values are in the range $[0, L]$

Logical Operations

$\cup$, $\cap$, Complement

OR, AND,

Operations

Spatial Operations

- Spatial operation are performed in spatial domain
  - Image is represented as $f(x,y)$
  - $X = 0, 1 \dots, M$
  - $Y = 0, 1 \dots, N$
  - Single pixel based operations
    neighborhood operations
    geometric trans formation

Transform Operation

- Image is transformed to other domain $g(u,v)$ (Transform domain)
- Operations are performed in the other domain
- Transformed operated image is inverse-transform to the spatial domain.

[1] Spatial Operations

★– Single pixel based Operation

work on pixel to pixel

- Intensity mapping

$$S = T(Z)$$

output image intensity — Operation — input image intensity

ex: getting the negative of 8 bit image $\Rightarrow T(Z) = 2^8 - Z$

★– Neighborhood Spatial Operations

work on the neighbors of the pixel

- The value of the pixel at x,y in the output image is calculated from a set of neighbor pixels centered at x,y in the input image.

ex: the calculated value = the average of the neighbors rectangle of dimensions M by N centered at the pixel

$$g(x,y) = \frac{1}{MN} \sum_{(r,c)\in S} f(r,c)$$

MN → ابعاد الجيران

S → sub image

★– Geometric Spatial Transformation.

- Common affine transformation matrices (depending on the chosen values of the elements of a matrix T)
  - Identity
  - Scaling
  - Rotation
  - Translation
  - Shear (vertical)
  - Shear (horizontal)

Dif : geometric transformation : is the mapping of the coordinates of each pixel in an image to another (rotated ---) pixel in the output image.

Consists of 2 basic Operations

[1] Spatial transformation of Coordinates

Forward Mapping

For each pixel in the input image find its location in the output image and assign its value

- Multiple output values are assigned to the same output pixel (Overlaps)
- Some output locations may not assigned values (Holes)

Inverse Mapping

For each pixel in the output image, find the location in the input image by applying the inverse transform, use the interpolation to calculate intensity value based on the intensities in the input image location

inverse mapping avoids holes and overlaps in the output image, so it is more efficient than forward mapping and preffered in geometric transformation application (such as matlab)

[2] intensity interpolation

- Is used to assign intensit. for the relocated pixels in processed image.
- Interpolation made using one of 3 methods
  1. Nearst Neighbor
  2. Bilinear
  3. Bicubic

* Image Registration

- Different images taken for the same scene At different times with different Viewing angles / distances
- In image registration, Input and output images are Known and Transformation matrix is unknown.
- Registration: the process registers the input image against the reference image. Find The Transformation T (reference image to input image) then apply T^{-1} on the input image.

Simple model for registration

$$x = C_1 V + C_2 W + C_3 VW + C_4$$
$$y = C_5 V + C_6 W + C_7 VW + C_8$$

where x, y: reference Coordinates.
V, W: input image coordinates

- Apply these two equations at four tie points to obtain 8 equations in 8 unknowns, Solve them for the unknowns ⇒ You got the model
  - Use the model to transform all input image to the reference image
  - After transforming the Coordinates, interpolation is used to assign intensity Values.

* Image Transform

$f(x,y)$ (Spatial domain) → Transform → $T(u,v)$ → Operation R → $R[T(u,v)]$ → Inverse Transform → $g(x,y)$ (Spatial domain)

* Linear 2-dimensions general transform

$$T(u,v) = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y)\, r(x,y,u,v)$$

and its inverse transform is

$$f(x,y) = \sum_{u=0}^{M-1} \sum_{v=0}^{N-1} T(u,v)\, S(x,y,u,v)$$

Where $r(\,)$, $S(\,)$ are the Transform and inverse Kernel.

If $r(x,y,u,v) = r_1(x,u)\, r_2(y,v)$ ⇒ where r_1, r_2 are functionally equals

* Note that each transformed pixel is calculated from all pixels in the input image and each inverse transformed pixel is calculated from all pixels in the transformed image.

Ex For linear 2 dimensions transform : Fourier Transform.

$$T = AFA \Rightarrow BTB = BAFAB \quad \text{if } B = A^{-1}$$
$$\therefore F = BTB$$

* Probabilistic Models

noise exist : if intensity values are treated as random quantities

Possible intensities Z_i , $i = 0, 1, 2, \dots, L-1$

$$P(Z_k) = \frac{n \cdot Z_k}{MN} \quad , \quad \sum_{k=0}^{L-1} P(Z_k) = 1$$

possible intensities for one pixel is equal to 1

mean (average) intensity levels (m)

$$m = \sum_{k=0}^{L-1} \frac{\boxed{Z_k} \cdot \boxed{n_{(Z_k)}}}{\underset{\text{no. of pixels}}{MN}}$$

← no. of intensity level appears

→ Z_k : intensity level for one pixel (random pixel)

$\sum_{k=0}^{L-1} Z_k$: Collection of intensity levels

Variance : → مدى توزيع القيم حول mean

$$\sigma^2 = \sum_{k=0}^{L-1} (Z_k - m)^2 \, P(Z_k)$$

Variance ≡ Second moment

Standard diviation : →

$$S.D = \sqrt{\sigma} = \sqrt{\text{Variance}}$$

- Variance and S.D are measures for image Contrast

  image contrast $\propto$ Variance and S.D

in general n^{th} moment $\sigma^n = \sum_{k=0}^{L-1} (Z_k - m)^n \, P(Z_k)$

- 3^{th} moment & pixel value
  - Positive → Values higher than mean
  - negative → Values Lower than mean
  - Zero → Values are distributed Uniformly over the mean.

Enhancement تحسين الصورة

(✓) Spatial domain
direct manipulation of pixels in the image plane

Frequency d...
modifying Fouri... transform of the image

lec : 6

Spatial Processing

Intensity Transformation

- Operates on a single pixel
  → neighborhood of size 1×1 (one pixel)
- App Contrast manipulation and image thresholding

- Change range of intensity
- intensity transformation is a spacial case of Spatial Filtering

Spatial Filtering

- Operates on neighborhood rectangle.

App: Contrast manipulation and proprocessing

- Filter the domain Coordinates

I Intensity Transformation

intensity transformation Functions

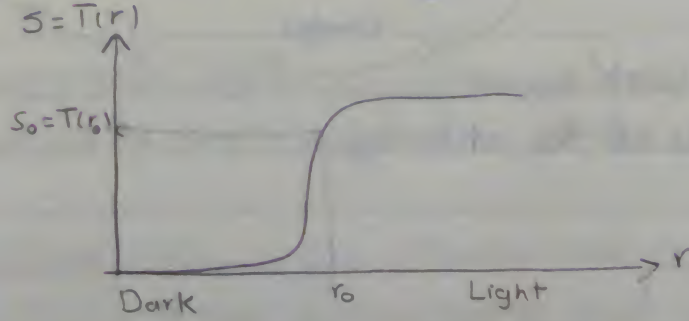
Basic intensity transformations

a) linear (negative and identity)
b) Logarithmic (Log and inverse log)
c) Power (n th power and n th root)

Piecewise linear transformation

a) Contrast stretching, threshold
b) Gray-level slicing
c) Bit-plane slicing.

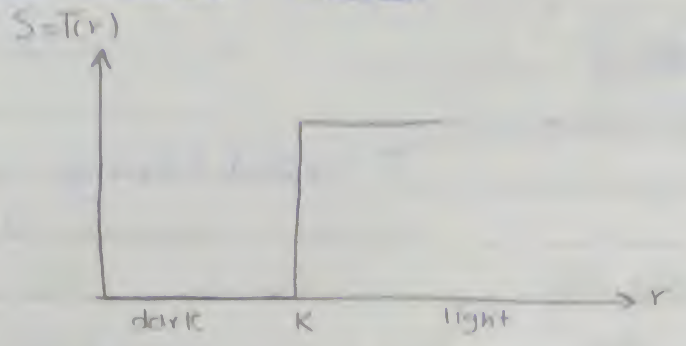
1 Contrast stretching



This Function increases the whiteness of the pixels near the white range and increases the darkness of the pixels neer the dark range.

* For the intermediate pixels, no much changes occurs

② Threshold Function

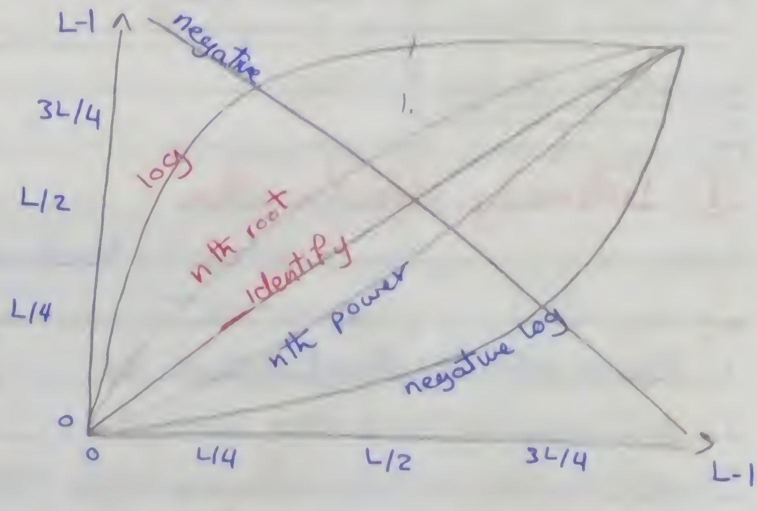


* put determined value to intensity "K" and the bigger than it equal to 1 and the smaller equal to 0

$$S = \begin{cases} 1 & r > K \\ 0 & r < K \end{cases}$$

③ Basic types of intensity mapping Functions

- Linear (change the intensity range)
- negative
- Logarithmic
- power



ⓐ Negative

$$\boxed{S = (L-1) - r = (2^K - 1) - r}$$

ⓑ Log

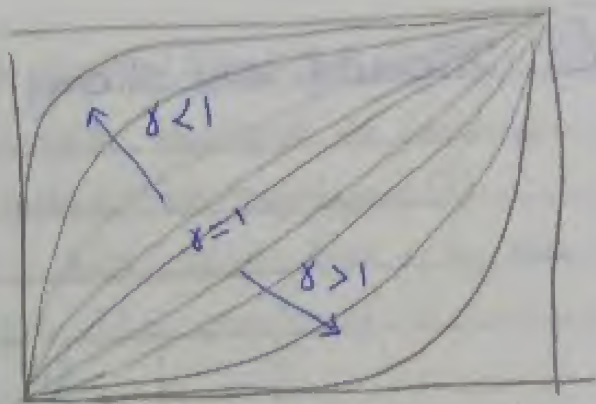
$$\boxed{S = C \log(1+r)}$$

Look Up Table : table has the intensity of input and output images

- **Log**: expand the details in the dark region
- **Reverse Log**: expand the details of the white region

Ⓒ power low (gamma)

$$\boxed{S = C\, r^{\gamma}}$$



App: Contrast manipulation

Over-Contrast
this means that the image is too dark

Sol
gamma mapping with $\gamma < 1$

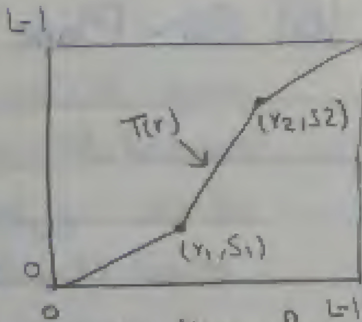
* big value of γ give acceptable image
لأنها بتقرب من $\gamma = 1$

Under Contrast (washed-out)
this means that the image is too light

Sol
gamma mapping with $\gamma > 1$

* Small value of γ give acceptable image
برضو لأنها بتقرب من $\gamma = 1$

④ Piecewise linear
is used for contrast stretching
- low Contrast image may result from.
  - poor illumination
  - lack of dynamic range in the Sensor
  - wrong setting when Capturing the image



piecewise linear fun

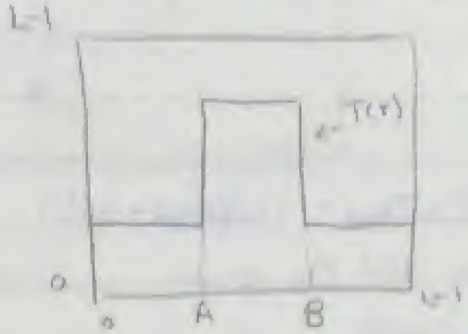
To linear stretch image $(r_1, s_1) = (r_{min}, 0)$ and $(r_2, s_2) = (r_{max}, L-1)$
To threshold the image $(r_1, s_1) = (m, 0)$ and $(r_2, s_2) = (m, L-1)$

where : r_{max} : max intensity level in the main Image
r_{min} : min intensity level in the main image.
m : average of intensity levels.

5 Intensity level slicing

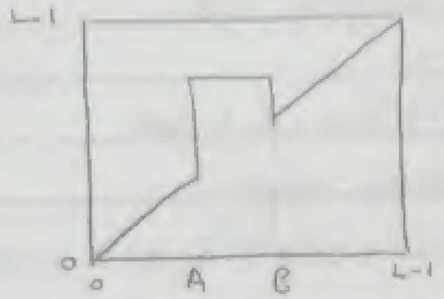
* Used to highlight a spatial part in the image by 2 ways:

① highlight the spatial part and dark the else



highlight Part A B
here 0 to A and B to L-1
are black

② highlight the spacial part and remain the else



highlight Part A B
here 0 to A and B to L-1
has no Change.

6 Bit-Plane Slicing

- Image divides into planes where nomber of planes equals to nomber of bits in one pixel ⟶
  8 bit / Pixel ⇒ 8 plane

6 Pixel each pixel has 8 bits

- Plane 0 show the intensity values of all b_0 in all pixels
  plane 1 show the intensity values of all b_1 in all pixels and so on
- First bit (b_0) ⇒ least segnefi (has less details)
  last bit (b_7) ⇒ Most segnefi (has more details)
  } So we can show only MSB that have most details.
- If we need to show plane 6, 7
  intenisty value of $b_6 * 2^5$ + intensity value of $b_7 * 2^6$
  and show the result

* Histogram (Note: we are still in Spatial Operations)

- Histogram used to make enhancement
- pixel (x, y) in no Color → binary image $f(x,y) = 0$ or 1

  in gray level → $f(x,y)$ takes values from 0 to 255

  this mean that we have 256 gray level

- We Know that any digital image has no. of pixels each pixel takes value from the range $0 \rightarrow 255$ ∴ one pixel ∈ one gray level

- For one gray level there are N pixels belongs to it
- Histogram is the relation between gray levels and nomber of pixels in image that belong to them

$$\boxed{h(r_K) = n_K}$$

where: r_K : gray level K , $K = 0 \cdots 255$

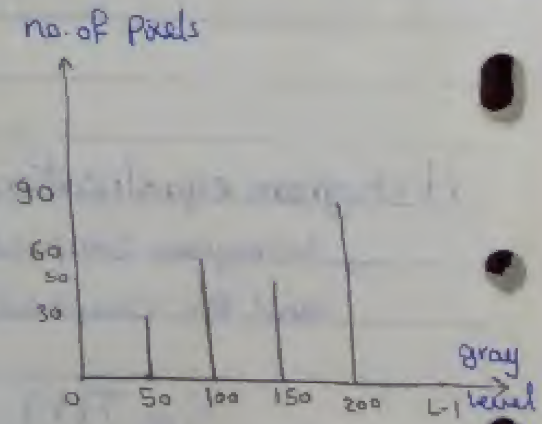
n_K : no. of pixels in image that belongs to gray level K

∴ Histogram of any gray level is the no. of pixels that belong to it.

Normalized histogram $P(r_K) = \dfrac{n_K}{MN}$ where MN: total no. of pixels

نسبة ال pixels لل gray level ⇐ r_K

$$\sum_{K=0}^{L-1\ (255)} P(r_K) = 1$$



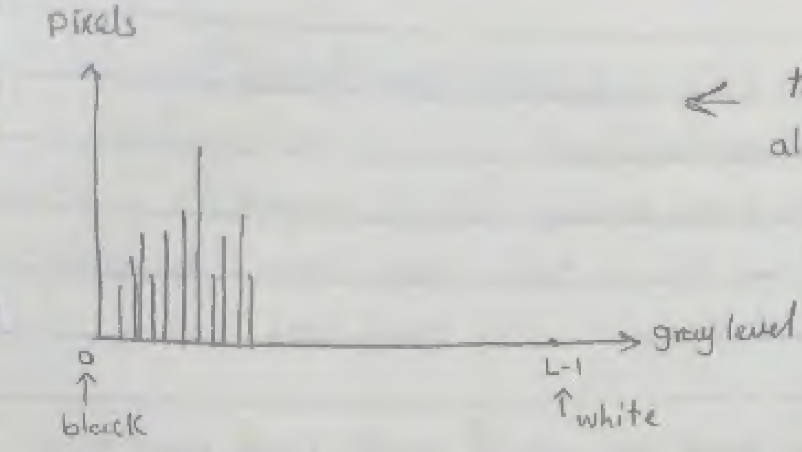
* Histogram is a discrete function between gray levels and no. of pixels

→ From the figure (for an image)

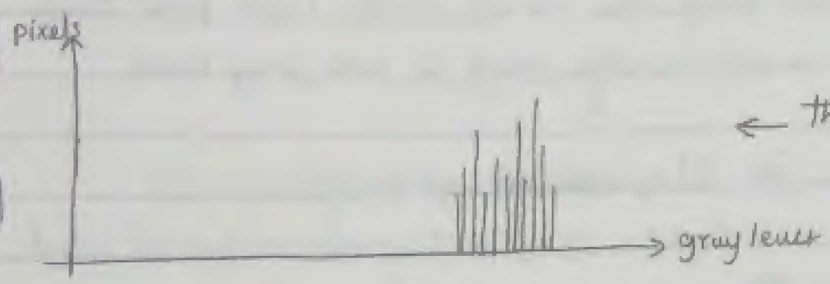
30 pixels have intensity value 50

60 pixels have intensity value 100

50 pixels have intensity value 150 and so on

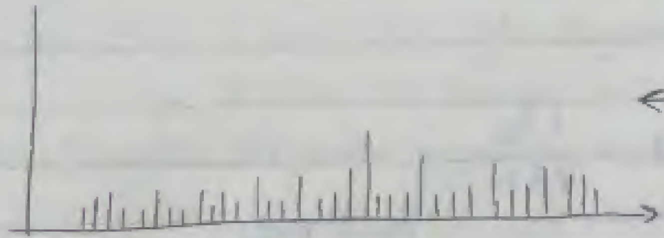


← this image is dark because all pixels have small intensities



← this image is Light

← this image low contrast



← this image high contrast

Histogram equalization

→ histogram Components is Uniformly distributeted on all intensity levels and the Component Value are all equals

$S = T(r)$ Choose $T(r)$ that achieve histogram equalization.

1. $T(r)$ is monotonically increasing
   if $r_2 > r_1$ then $T(r_2) \geq T(r_1)$ satisfied
2. To obtain image in the same dynamic range
   $0 \leq T(r) \leq (L-1)$

* Histogram and probability density Function.

Original Image with $P_r(r)$ $\xrightarrow[S=T(r)]{\text{mapping}}$ Reference Image with $P_s(S)$

* we have original image need to make histogram equalization on it to get reference image this mean that we need to Change the intensity value for Some pixels to another value using transfer function
  - $P_r(r)$ & $P_s(s)$ are Known
  - $T(r)$ is unknown
  - we need to Find $P_s(s)$ after mapping that gives equal values uniformally distributed histogram Components (equalized histogram)

$$P_s(s) = P_r(r) \left| \frac{dr}{ds} \right|$$

$$S = T(r) = (L-1) \int_0^r P_r(w)\, dw$$

$$\therefore \frac{ds}{dr} = \frac{d\,T(r)}{dr} = \frac{d\,(L-1)\int_0^r P_r(w)\,dw}{dr} = (L-1) \cdot P_r(r)$$

$$\therefore P_s(s) = P_r(r) \left| \frac{1}{(L-1)\cdot P_r(r)} \right| = \frac{1}{L-1}$$

* histogram equalization in Contenous Form

$$S = T(r) = (L-1) \int_0^r P_r(w)\, dw$$

* histogram equalization in discrete Form

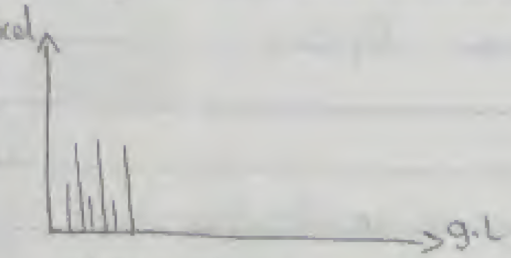
$$S_K = T(r_K) = (L-1) \sum_{j=0}^{K} P_r(r_j) = \frac{(L-1)}{MN} \sum_{j=0}^{K} n_j$$

$K = 0, 1, \ldots, L-1$

* Histogram App to Images

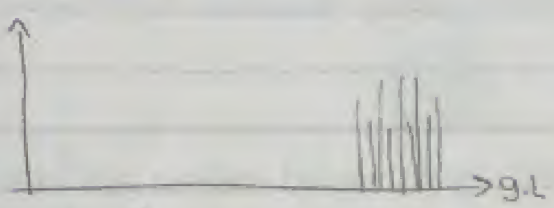
4 images for the same Object

1



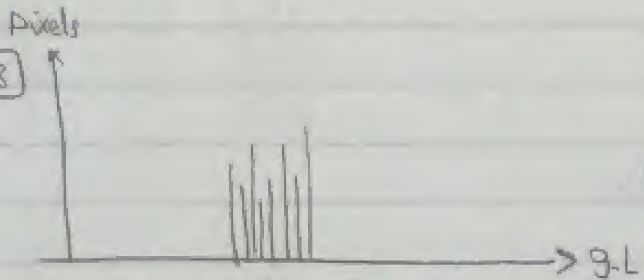
dark image

2



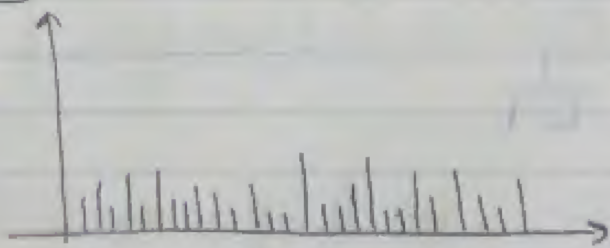
Light image

3



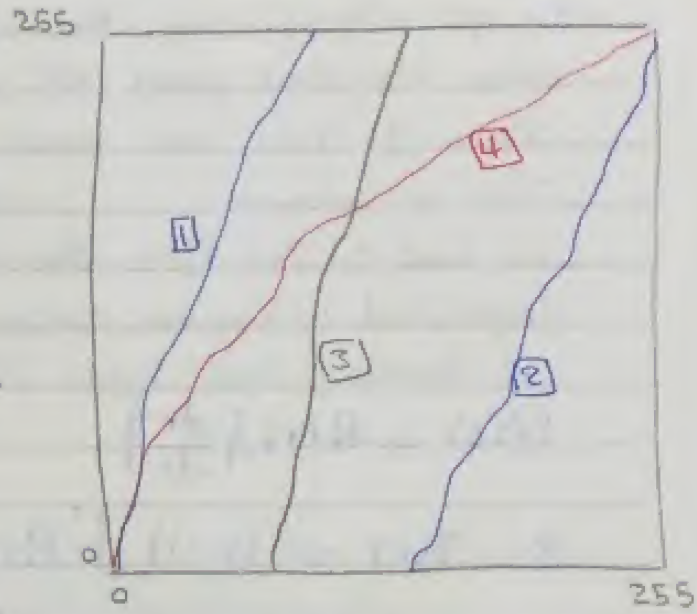
Low Contrast image

4



high Contrast image

$\Longrightarrow$



<u>Notes</u>: 1 in dark image we work on first gray levels to get histogram equalization

2 in Light image we work on last gray levels and so on.

3 histogram equalization is not always best solution

Histogram Equalization Example

* L : max intensity in the image ($L = 255$ if there is a white pixel)

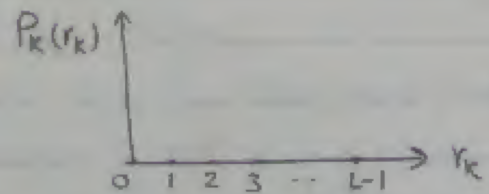
$L = 2^K$ where K no. of bits

* r is the set of intensity values $[0, L-1]$

$\Rightarrow$ given r_k and n_k $\boxed{MN = 64 \times 64 \text{ pixel}}$

$\boxed{1}$ Calculate $P_r(r_k) = \frac{n_k}{MN}$ and draw relation between $P_r(r_k)$ & r_k

r_k	n_k	$P_r(r_k)$
r_0		



Discrete

$\boxed{2}$ S from 0 to $L-1$

exact value

$$S_K = T(r_K) = \frac{L-1}{MN} \sum_{j=0}^{K} n_j$$

$$S_0 = \frac{7}{MN}(n_0), \quad S_1 = \frac{7}{MN}(n_0 + n_1), \quad S_2 = \frac{7}{MN}(n_0 + n_1 + n_2) \ldots$$

n_k	S	Exact	Quantized
790	S_0	1.33	1
1023	S_1	3.08	3
850	S_2	4.55	5
656	S_3		6
329	S_4		6
245	S_5		7
122	S_6		7
81	S_7		7

Then Calculate $P_s(S_k) = \frac{n_k}{MN}$

$P(S=1) = 790/4096$

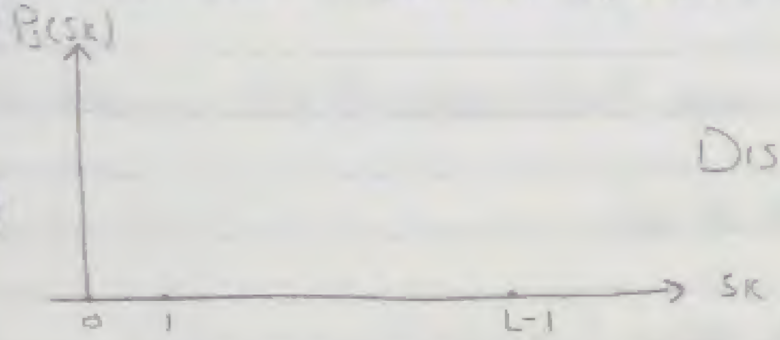
$P(S=3) = 1023/4096$

$P(S=5) = 850/4096$

$P(S=6) = (656+329)/4096$

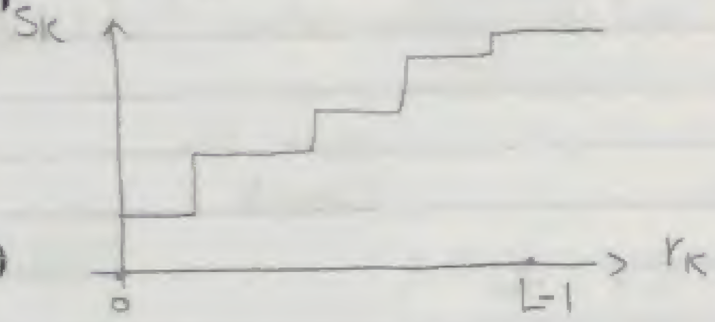
$P(S=7 = (245+122+81)/4096$

Drow relation Between $P_s(s_k)$ & s_k



Discrete

Then Drow Contenous relation Between r_k & s_k



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* Histogram matching

like equalization but divided into 2 classes
① global (on all pixels)
② Local (on part of the image)

[1] global

→ given Specified Image that we wish to reach it in Z

→ we have input Image r_K , $P_r(r_K)$
and Can get S_K , $P_s(S_K)$
here we need to get S_K that neer to Z_K to reach to Specified image

ⓐ r_K , $P_r(r_K)$ → draw relation (discrete)

② S_K , $P_s(S_K)$ → draw relation

③ Z_q, $G_z(Z_q)$ given → draw relation (cont)
make $G^{-1}(Z_q)$ to get Z

Z_q	$G(Z_q)$	S_K
$Z_0=0$	0	
$Z_1=1$	0	
$Z_2=2$	0	
$Z_3=3$	1 ←	1
$Z_4=4$	2 ←	3
$Z_5=5$	5 ←	5
$Z_6=6$	6 ←	6
$Z_7=7$	7 ←	7

← exist

Take aproximate value

← exist

→ draw relation $P_z(Z_q)$, Z_q.

S_K	Z_q
1 →	1
3 →	4
5 →	5
6 →	6
7 →	7

Contrast enhancment

1. Using histogram

$$\mu_s = \sum_{i=0}^{L-1} (r_i - m) P_r(r_i)$$

2. Using Pixel intensity Values

n=2 global Variance

$$\mu_s = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} [f(x,y) - m]^{n}$$

Filters

Frequency domain

(Low Pass Filter)

pass low freq

reject high freq

Spatial Domain

. Filter is mask , Kernal , window

linear filter

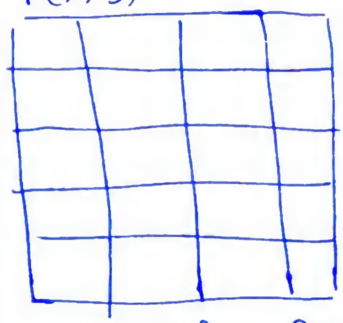
. linear operation

non-linear filter

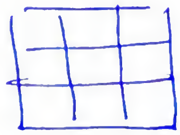
non-linear operatio

$\boxed{\text{* Linear}}$

f(x, y)



w



m x n

$m = 2a + 1$

$n = 2b + 1$

image before filterring

g(x,y)

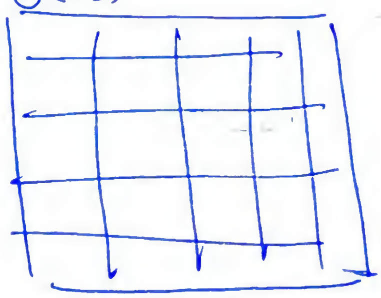


Image after filtering

$$g(x, y) = \sum_{s=-a}^{a} \sum_{t=-b}^{b} w(s,t)\, f(x+s, y+t)$$

1) linear Filter has 2 methods

Correlation

$g(x,y) = w(x,y) \star f(x,y)$

$= \sum_{s=a}^{a} \sum_{t=b}^{b} w(s,t) f(x+s, y+t)$

mask : 12328

Image 0000 0001 0000 0000

12328

0 : P_1 after mask = 0

000 10000
12328
$P_2 = 0$
00010000

00010000
1 2328
$P_4 = 8$
000800000

00010000
12328
$P_5 = 2$
00020000

Result : 00 $\boxed{08232100}$ 00

Convolution

$g(x,y) = w(x,y) \star f(x,y)$

$= \sum_{s=a}^{a} \sum_{t=b}^{b} w(s,t) f(x-s, y-t)$

mask : rotated = 82321

image 000 0001000 0 0000
82321
$P_0 = 0$

0001000 0
82321
$P_1 = 0$

:

0001 0000
82321
$P_4 = 1$

00010000
82321
$P_5 = 2$

Result = $\cancel{0}$0 $\boxed{01232800}$ $\cancel{0}$0

Smoothing (low Pass)

Linear Filter

Standard | Weighted

mask

1	1	1
1	1	1
1	1	1

$* \frac{1}{9}$

1	2	1
2	4	2
1	2	1

$* \frac{1}{16}$

Smoothing Order statistics : Median

110	120	90	
91	94	98	
90	95	99	

$\rightarrow$ 95

① $\underbrace{90, 90, 91, 94}$, 95, $\underbrace{98, 99, 110, 120}$

Spatial Filters : Sharpening (High Pass)

① Laplace

first driv | 2nd driv

0	-1	0
-1	4	-1
0	-1	0

-14 = 1st driv

الناتج نطلعه

-74 1st driv

4*[]4-1*1- = $\boxed{-14}$

154 - 14 =

result = الصورة الأصلية + 2nd driv

184 - 74 = 80

② Sobel

detects horisontal edges

-1	-2	-1
0	0	0
1	2	1

detected vertical

-1	0	1
-2	0	2
-1	0	1

* What is a pattern?

A set of instances that share some regularities and similarities
- Is repeatable . is observable , using sensors.
- may have noise and distortions.

<u>Examples</u>
- Image object
- Text document
- Speech patterns
- Signal waveforms

* Pattern Recognition : the science that concerns the description or classification of measurements

<u>Areas</u>
- Image processing
- Vedio processing
- Speech processing
- Neural language pro
- Machine Learning
- Neural Networks
- DataBase engineering
- Bioinformatics.

Challenges

the appearance of an object can have a large range of variation due to:
- Illumination
- Changes in Sharp
- Context
- Viewpoint Changes.

. different views of the same object can give rise to widely different images

→ Object Recognition Apps
- Quality Control and assembly in industrial plants.
- Robot navigation
- Monitoring and surveillance.
- Automatic exploration of image database.